GEOLOGIC RECONNAISSANCE OF THE SOUTHERN PART OF THE TAOS RANGE, NEW MEXICO

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INTRODUCTION

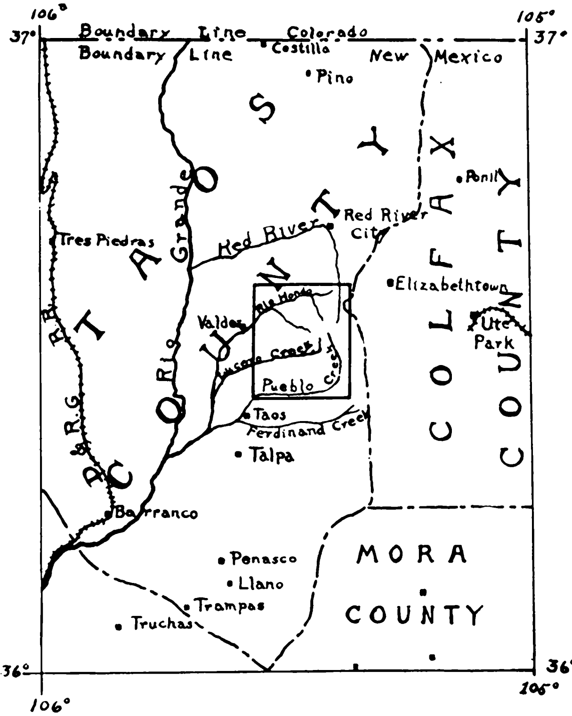
The Taos Range is a part of the Sangre de Cristo Range. Not more than about two-fifths of the Sangre de Cristo Range extends into New Mexico. The larger portion, the Culebra Range and the Sierra Blanca, lies in southern Colorado. Where the Culebra Range crosses the boundary line into New Mexico it splits into two great uplifts, the Taos Range and the Cimarron Range, which find their continuation in the Mora Range and Las Vegas Range respectively. The Taos Range proper is about 30 to 35 miles long and has an average width of 15 miles. Its northern limit is Costilla Creek, its southern Ferdinand Creek. The region described in this report is situated in north central New Mexico near the Colorado line. (See Fig. 1.)

The southern part of the Taos Range, as seen from the Rio Grande Valley to the west of it, offers an imposing view. From an altitude of about 7,000 feet, the elevation of the valley above sea-level, a number of peaks rise to snowy heights within a distance of a few miles. The mountain front is deeply incised by Pueblo Creek, Lucero Creek, and Rio Hondo, which flow westward to, the Rio Grande. (See topographic map, Plate XIII.)[1] The Red River (called "Colorado Creek" by Stevenson[2]), of which only a few miles are in the area mapped, has a northerly direction before it turns westward and breaks through the main chain of the mountains below Red River City.

[1] The attached topographic map was made by the writer who used as basis a map compiled by the United States Land Office and the United States Forest Service. The peak which is called Taos Peak by Stevenson is generally referred to as Wheeler Peak now.

[2] John J. Stevenson, "Report upon Geological Examinations in Southern Colorado and Northern New Mexico, 1878–1879," *Report U.S. Geog. Sur. West of the 100th Meridian*, Vol. 3, Supplement, 1881.

On the east of the Taos Range the broad Moreno Valley separates the Taos Range from the Cimarron Range, which is nearly as high. On this eastern slope of the range watercourses are rather scarce.



Scale 1:1,000,000

FIG. 1.—North central New Mexico showing location of area mapped. Copied from Plate I of *Professional Paper No. 68.*

DESCRIPTIVE GEOLOGY

The Taos Range is built up of three great rock systems. The pre-Cambrian gneisses, schists, and granites constitute the basement and greater part of the core of the uplift. Upper Carboniferous strata of great thickness are turned up on the east and south sides of the range. These older systems are intruded by stocks and dikes of granite and rhyolite porphyry respectively.

Along the western slope of the mountains large alluvial fans spread over the plains toward the Rio Grande for a number of miles,

where they are finally encroached upon by the basalt flows of the Rio Grande Valley.

In Stevenson's report[1] the mountains north and west of Pueblo Creek are assigned to the "Taos axis," those south and east of that creek to the "Mora axis." It was believed that the Taos axis does not continue beyond Pueblo Creek, but that a new one, the Mora axis, begins at the head of the Red River and runs southward, parallel to the Taos axis on the west, until the latter vanishes. No such structural division could be noticed by the writer between the Taos Range and Mora uplift south of it. The misconception was probably due to the belief that the Pennsylvanian strata exist also on the west side of the range.[2] The sedimentary outliers on the main range, to be described later, when viewed from the distance, easily give such an impression. No new axis begins in this district, but the Taos axis pitches steeply toward the south and the pre-Cambrian rocks disappear at the junction of Pueblo Creek and Indian Creek beneath the Pennsylvanian strata, which form here an uninterrupted anticline across the range.

In the region mapped this anticlinal structure is absent. No Pennsylvanian sediments were found on the western slope north of Pueblo Creek. The mountains present a bold fault scarp facing west. Whether sedimentary rocks of Pennsylvanian age underlie the thick débris fans and basalt flows or not is unknown at the present time. But farther north, in Colorado, Siebenthal mentions their occurrence on the west side of Culebra Peak and the anticlinal structure of the Sangre de Cristo Range at that latitude.[3]

PRE-CAMBRIAN CRYSTALLINE ROCKS

Ancient gneisses and schists.—The most ancient rocks are amphibolite and chlorite schists and gneisses that grade into greenstone in places. They cover the larger portion of the northwestern half of the area mapped, form an almost continuous outcrop along the western scarp of the range, and cap all of the high peaks with the exception of Old Mike. Lack of space will not permit to

[1] *Op. cit.*, pp. 41–42. [2] *Op. cit.*, p. 42.

[3] C. E. Siebenthal, "Geology and Water Resources of the San Luis Valley, Colo.," *U.S. Geol. Survey Water Supply Paper 240* (1907), p. 34.

describe these occurrences in detail, but as a rule sheeting in these rocks has a steep westerly to northwesterly dip. Nowhere in the ancient rocks were any close folds or signs of distortion and twisting seen, as might be expected in schists, and as were actually observed in the metamorphosed sedimentary rocks described below.

Granitic gneisses occupy a rather obscure position with respect to the more basic varieties, and may, in some cases, be of the same age as the batholithic granite intruding the older schists. In one instance, on Old Mike, this relationship was proved. Here the gneiss could be traced to its parent rock, the granite beneath.

The following outcrop deserves special attention in the opinion of the writer. The plateau south of Lucero Peak, between the Salazar and Lucero Canyon, is covered with a dark-green, fine-grained hornblendite and greenstone which resemble a flow. A "sheet" at least 200 to 300 feet thick, of dark, indistinctly schistose rock, overlies the granitic batholith. Ramifying apophyses from the granite beneath can be seen in the greenstone. Just north of Lew Wallace Peak lies a relatively small mass of greenish-gray, very fine-grained altered diabase. No cleavage or regular sheeting is visible in it. Whether this rock bears any genetic relation to the sheet on the opposite side of Lucero Canyon, just described, or not could not be determined.

Metamorphosed sedimentary rocks.—The metamorphosed pre-Cambrian sediments occupy belts of greatly varying width between the Pennsylvanian series on the southeast and the granite batholith on the northwest. The assumption that the batholithic granites are younger than the metamorphosed sediments is based upon the attitude of these formations, which flank and abut against the gneisses and granites. (See Fig. 2.) The formations are chiefly composed of quartzites and quartz and chlorite schists, and are undoubtedly of sedimentary origin.

The area of quartzite as outlined on the map claims accuracy only along the western margin. The eastern limit could only be estimated; therefore the outcrop may be somewhat narrower. The dip of the quartzite is steeply eastward, varying from 45° to 90°. Jointing at right angles to the beds is the rule. Figure 3 shows a nearly perpendicular exposure of quartzite, 300 feet high,

northeast of Ben Hur Lake. No trace of the bedding of the original sandstone was detected, perhaps due to the possible identity of the original bedding and the sheeting. The attitude and character of the quartzite strongly suggest this possibility to the writer. The color of the formation as a whole is yellow, but the southern end of it becomes reddish and purplish gray.

Southeast of Sacred Lake the very steeply dipping quartzite overlies a very much folded and twisted, thinly laminated chlorite schist. The foliation of the latter, as a whole, is parallel to that of quartzite. What appears to be a continuation of the quartzite

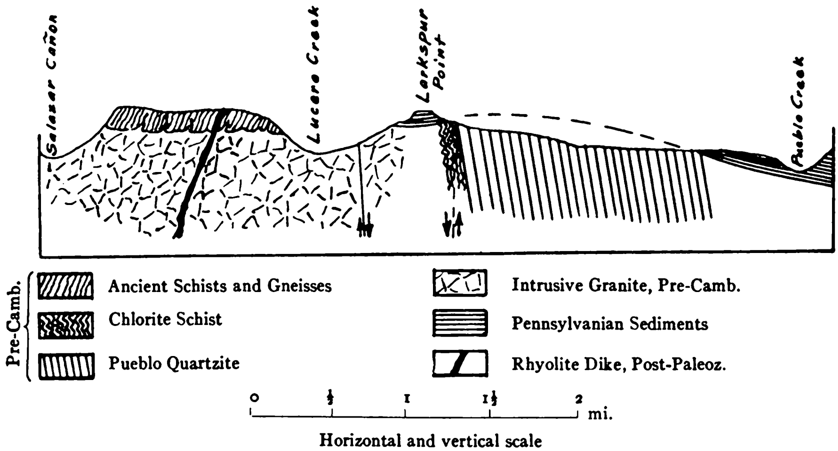


FIG. 2.—Cross-section from Salazar Canyon to Pueblo Creek, along line *A-B* on map.

and schist is seen half a mile southwest of this locality, just below Larkspur Point. Here steeply tilted chlorite epidote schist forms a cliff of conspicuous gray color. Strike and dip of the sheeting are very similar to that of the quartzite. Southwest of Pueblo Peak, adjacent to and north of the Pennsylvanian sediments, steeply inclined quartz-schist forms sharp craggy outcrops and cliffs. The formation flanks Pueblo Peak parallel to the fault line for an unknown distance toward the west.

Intrusive granites.—The distribution and composition of the granites suggest a close genetic connection between the individual areas. It is highly probable that all belong to one great batholith

which arched up the overlying formations and metamorphosed the sediments.

One of the largest exposures of this batholith is along the Rio Hondo, where a light-gray, very coarse biotite granite outcrops. It weathers easily and forms curiously shaped pinnacles in some places. Also along Lucero Creek a pinkish, more or less gneissoid, granite is found. The latter is also the predominating rock in the Salazar Canyon, and from here a broad belt of it passes beneath Lucero Peak to Old Mike.

FIG. 3.—Pueblo quartzite on Ben Hur Lake. Looking northeast. Unconformity on upper left. Pennsylvanian beds nearly at right angles to sheeting of quartzite.

The rocks from Old Mike and Red Dome show every gradation from a typical red granitic gneiss to a medium-grained biotite granite. Medium-grained biotite granite varying in color from pink to greenish gray also covers a large part of Red River Canyon, especially on the west side. A detailed examination was impossible in this part of the district.

Half a mile west of Larkspur Point pink medium to coarse-grained granite outcrops on the steep slope above Indian Creek. South of Larkspur Point the continuation of this outcrop is found in contact with remnants of ancient schist that caps a part of Larkspur Point. Farther toward the southeast the gneissoid granite is exposed along the northwestern tributary of Pueblo Creek for a distance of two and a half to three miles.

Basic dikes.—A number of basic dikes are intrusive into the granite of the batholith. Their age is probably pre-Cambrian. The most prominent one occurs just east of the highest point of Pueblo Peak and has a width of 100 to 150 feet. Its trend corresponds to that of the others, which have a northwest to southeast direction. In composition and texture it approaches a gabbro.

Two pre-Cambrian inliers that cannot be classified outcrop on Pueblo Creek. Quartz and mica schists and some amphibolite are the only rocks in these inliers seen by the writer.

CARBONIFEROUS SEDIMENTARY ROCKS

In the district mapped all sedimentary rocks belong to the Pennsylvanian series. Stevenson[1] described them as Carboniferous, attempting no further divisions then. Later writers, especially W. T. Lee,[2] who examined parts of this series farther east and north, recognized them as belonging to the Pennsylvanian series only. A number of fossils, collected by the present writer near the base of the sedimentary series, belong to the Pennsylvanian fauna. Six species were identified: *Lopophyllum profundum*, *Siminula subtilita*, *Spirifer cameratus*, *Spirifer rockymontanus*, *Productus cora*, *Productus semireticulatus*.

No generalizations concerning the thicknesses and divisions of the series can be given in this paper with the exception of the statement that by far the largest portion of the beds is composed of clastic material. The lowest member is usually a basal conglomerate grading into a sandstone, but in some localities limestone overlies directly the pre-Cambrian, and the sequence is reversed. It is very common to see a limestone in sharp contact with a coarse clastic in some places. On the other hand, formations hundreds of feet thick are found in which the transitions from one member into another are very gradual. Lithologically very similar beds of clastic material occur at many different horizons of the series and some of them are of such thickness that even considerable displacements by faults may be easily overlooked. The fact that all the faults seen by the writer in the sediments are normal and that evidence of folding due to lateral compression is absent seems to indicate that the Taos Range, if not the whole Sangre de Cristo Range, was formed solely by intrusive activity, probably in early Tertiary time.

[1] *Op. cit.*

[2] W. T. Lee, "Geology and Paleontology of Raton Mesa and Other Regions in Colorado and New Mexico," *Prof. Paper 101* (1918), pp. 41–42.

Distribution of the sediments.—The sedimentary rocks cover portions of the Pueblo Creek and Red River drainage basins, and extend far beyond the southern and eastern margins of the area mapped. While the thickness of the formations may be estimated at several thousand feet, at least 2,500 feet in the southeast corner of the district, erosion has reduced the thickness of the sediments toward the northwest to less than 300 feet above Sacred Lake.

The contact of the sediments with the pre-Cambrian rocks follows approximately a line from the southwest corner of the quadrangle to a point on Starvation Creek, about 1 mile south of Pueblo Peak. A normal fault of unknown displacement, probably relatively small, has sharply upturned the sandstones and limestones against quartz-chlorite schists west of Starvation Creek. Here at the bottom of the creek 100± feet of dense gray non-fossiliferous limestone are seen the base of which is not exposed. On it rests a dense, brownish-gray, arkosic sandstone that is brownish red when weathered. This rock caps most of the ridges and is of great thickness.

Farther east, on the high divide between Pueblo Creek and Lucero Creek, the foregoing limestone is overlain by a greenish-gray calcareous and arkosic grit. This grit is of wide extent and great thickness, not only in this district, but beyond its limits. At certain horizons this rock is replete with fossil fragments, especially crinoid stems. It becomes gradually coarser toward the top of the formation and changes to a conglomerate which contains subangular pebbles of quartz, gneiss, granite, and schist. They do not exceed a diameter of 1 inch, but attain greater dimensions on Burned Ridge.

About 1½ miles south of Larkspur Point, where the strata rest on pink granite, the beds dip steeply soutwestward. The basal conglomerate clearly derived from the pre-Cambrian rocks beneath grades into sandstones, grits, and conglomerates. They are of great thickness and constitute no definite, sharply separated members. The attitude of the beds in connection with the dip of the same formation in the opposite direction on the southwest slope of Burned Ridge, near a point where a fault crosses Meyer's Creek, indicates a synclinal structure whose axis runs at right angles to Burned Ridge and pitches southeast.

At the head of Pueblo Creek the Pennsylvanian rests on pre-Cambrian quartzite. A north-south fault crosses the divide between Red River and Pueblo Creek, bringing the sandstones and grits into juxtaposition to the granite on the west. A little farther north two minor step faults cross the ridge from northwest to southeast. North of this exposure the sedimentary rocks are confined almost entirely to the area east of Red River. The river has cut a deep canyon into the sedimentaries, exposing on the east slope a thickness of nearly 1,000 feet of the Pennsylvanian. About 200 feet above the creek bottom the following approximate section is exposed:

	Feet
Red sandstone, very fine grained	100–150
Arkosic, light-colored sandstone, at least	200
Gray, fossiliferous limestone	50±
Dark-gray shale, carbonaceous in places	50±
Light-gray quartz conglomerate	40±
Concealed base	.....

A number of outliers of the Pennsylvanian are situated on the east slope of the main range and extend from Bull of the Woods to the head of Indian Creek. The most interesting outlier, a block faulted down on at least three of its four sides, lies east of Larkspur Point. (See Fig. 2.) A partial section of it measured just south of Sacred Lake is given below:

	Feet
15. Light-gray, very hard and massive arkosic sandstone	15
14. Brownish-gray, shaly limestone	30
13. Lime cemented conglomerate (description below)	20
12. Puddingstone conglomerate	10
11. Dark-red, very dense shale	20
10. Light-gray arkosic sandstone	12
9. Puddingstone conglomerate	25
8. Gray, massive, argillaceous limestone	45
7. Light-brown, medium-grained calcareous grit	20
6. Grayish-green shale, non-laminated	6
5. Puddingstone conglomerate (very coarse)	25
4. Brownish-gray, gritty limestone, fossiliferous	21
3. Red shale, somewhat arenaceous	9
2. Puddingstone conglomerate (extremely coarse)	32
1. Dark-red, very dense, massive shale	15+
	305

Concealed base about 50+ feet above schist

Of special interest in the outlier are the five members listed as puddingstone conglomerates on account of their unusual texture and composition. Their color as a whole is dark red. Joints and bedding planes are few and far apart in the three lower members. The lowest one (No. 2) of the formation consists of very angular "pebbles" and platy fragments of green chlorite and gray quartz-schist and gray slate, varying in size from mere sand grains to great bowlders 3 to 4 feet in diameter. They are imbedded in a red argillaceous and arenaceous cement, which makes up 80 to 85 per cent of the volume of the conglomerate. The highest member of the conglomerates (No. 13) which contains pebbles not exceeding 1 inch in diameter has only calcite as cement, which contains abundant fossil fragments.

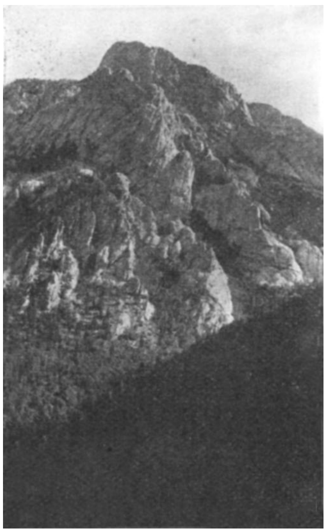


FIG. 4.—Opal Peak. Looking northeast. Center of porphyry stock with nearly vertical sheeting.

POST-PALEOZOIC IGNEOUS ROCKS

Though outcropping in areas 5 to 7 miles apart, the Red River rhyolite flow, the intrusive Opal Peak porphyry, and the numerous rhyolitic dikes are chemically and mineralogically much alike and probably of the same age. They are certainly post-Carboniferous, for one of the dikes cuts the Pennsylvanian beds on the divide east of Red River.

Only a part of the thick rhyolite porphyry flow on Red River lies in the area mapped. The rock is light gray in color. The white porphyry of the extremely rugged Opal Peak and Cuchilla de Media lying between the darker gneisses and granites offers a conspicuous color contrast. The porphyry in spite of its prominent sheeting (Fig. 4) is very soft, and no dark minerals were seen in it.

The scattered white rhyolite porphyry dikes, intrusive into the pre-Cambrian rocks, as a rule have a northwesterly trend and steep or vertical dip.

GEOLOGICAL HISTORY

While the pre-Cambrian history of the Taos Range must necessarily remain rather obscure until further investigation and correlation with other regions, some of the events may be enumerated with more or less accuracy. Nothing is known about the origin of the ancient gneisses and schists. During the long erosion interval that exposed them and probably reduced the ancient mountains to base level, thick clastic deposits accumulated along the eastern and southern margins of the area now occupied by the granite batholith.

Upon this time of great erosion a period of intense orogenic movement followed, probably accompanied or closely succeeded by the intrusion of enormous volumes of granitic magma into the overlying schists, gneisses, and sediments. Later a number of basic dikes pushed their way into this batholith. No record of the geologic events that followed is preserved until Pennsylvanian time.

At the beginning of this period the present site of the range most likely formed the eastern shore of a considerable land mass west and northwest of it. Siebenthal, in his study of the San Luis Valley, has come to the same conclusion.[1] The very coarse and angular basal conglomerates of the Pennsylvanian leave no doubt as to the near-shore conditions that existed during their formation. The deposition of the puddingstone conglomerates and breccia and such bowlder beds (some bowlders with a diameter of 25 to 50 feet) as S. F. Emmons mentions farther north, on the east side of the Sangre de Cristo Range,[2] can have been brought about only by talus and wash from a precipitous coast directly into deep or quiet water. The fact that the pebbles of all conglomerates consist of pre-Cambrian schists, gneisses, quartzites, and granites suggests a land surface composed chiefly of these rocks. The enormous thickness of the strata leads also to the conclusion that a gradual sinking of the coast and progressive submergence from the east to the west took place during this period.

[1] C. E. Siebenthal, "Geology and Water Resources of the San Luis Valley, Colo.," *U.S. Geol. Survey Water Supply Paper 240* (1907), pp. 50–51.

[2] S. F. Emmons, "Orographic Movements in the Rocky Mountains," *Geol. Soc. Amer. Bull.*, Vol. I, pp. 245–86.

A more difficult problem arises from the question when deposition of sediments ceased. Stevenson speaks of the Jura Trias "Red Beds" that occur farther east and south as resting conformably upon the Carboniferous.[1] Lee, on the other hand, would rather assign them, at least partly, to the Pennsylvanian system.[2] He also favors the assumption that during Cretaceous time the sea covered practically all of the territory now occupied by the southern Rocky Mountains.[3] Until further evidence is found to prove that this view is correct, the present writer is inclined to believe that the site of the Taos Range proper during the Cretaceous was not, or only for a short epoch, an area of deposition for the reason that no Cretaceous sediments have been discovered on the west side of the Culebra and Mora ranges as far as can be learned from the available literature.

Probably during early Tertiary, deep-seated intrusive activity resulted in the uplift of the Sangre de Cristo Range. Since that time erosion has been at work continually. Glaciation in recent time has been an especially powerful agent in the process of destruction of the mountains.

ECONOMIC GEOLOGY

It is not likely that this district will ever attain great importance on account of its mineral resources. Three deserted camps on the Rio Hondo tell of an attempt to extract gold at South Fork and Almozzet, and copper at Twining. Lindgren has described these occurrences.[4]

A number of short prospect tunnels are situated in and close to some of the rhyolite dikes near Fairview Mountain and Lucero Peak where pyritization has altered the schist. Another claim is at the head of Elm Creek, near the base of the Pennsylvanian, where a narrow vein of barite and galena outcrops in the sediments.

[1] *Op. cit.*, p. 85.

[2] *Op. cit.*, p. 39.

[3] W. T. Lee, "Relation of the Cretaceous Formations to the Rocky Mountains in Colorado and New Mexico," *U.S. Geol. Survey Prof. Paper 96* (1916), p. 40.

[4] W. Lindgren and L. C. Graton, "The Ore Deposits of New Mexico," *U.S. Geol. Survey Prof. Paper 68* (1910), p. 83.